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A review of the Dutch ecosystem for building integrated photovoltaics

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Abstract

Building integrated photovoltaics (BIPV) is one of the most promising solutions to generate renewable electricity in the built environment. BIPV applications can replace regular building components into prefab integrated components that at the same time generate electricity, contributing to the aesthetics in the built environment. In this paper we thoroughly review the existing BIPV stakeholders, the BIPV ecosystem and policy and legislation for BIPV in the Netherlands. The information that is provided throughout this research and the conclusions that were drawn should be taken into account by the government, academia and the BIPV industry when further designing the BIPV (export) strategy for the Netherlands.

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Keywords: Building Integrated Photovoltaics; BIPV; photovoltaics; aesthetics; built environment; renewable energy; solar energy; the Netherlands

1. Introduction

Generating renewable electricity in the built environment increasingly is done by means of building integrated photovoltaics (BIPV) applications that replace regular building components [1]. Prefab integrated components that at the same time generate electricity contribute to the aesthetic value of a building, and allow architects to design (near) zero energy buildings. The concept is distinctive from regular solar energy applications, since the PV function is integrated into the building envelope instead of placing the solar module on the roof (Building Added (or Adapted) PV, BAPV).

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BIPV is currently positioned primarily as a niche-product, making up about 1-3% of the total PV market with a total installed capacity worldwide of 1.0 GWp [1]. In this study, BIPV is referred to as a system that includes at least one functionality in the building envelope in addition to electricity generation [2].

Three common building elements that are suitable for state-of-the-art BIPV are pitched and sloped roofs, flat and curved roofs, and façades [3]. Today, the most preferred location for BIPV elements or systems is usually the rooftop due to less shadowing and therefore generally more solar radiation and higher power generation, but façades become more and more popular from an aesthetic point of view [4]. Flexibility in shape, size and colour are important characteristics of BIPV [2]. The BIPV applications that are generally used are 1) BIPV foil or thin film (high flexibility and light weight), 2) BIPV tiles (concerning 57.8% of BIPV roofing systems [5]), 3) BIPV modules (similar to BAPV, but weather proofing and in-roof), and 4) solar glazing (e.g. transparent BIPV roofs at train stations of Utrecht and Rotterdam) [6].

2. Structure of the research

2.1. Stakeholder analysis (methodology)

The stakeholder analysis consisted of the following phases [7]:

1. Inventory of involved parties: The inventory was made at the sectoral level and parties were identified according to the Triple Helix (Government, Industry and Academia) [8].
2. Define interest of each stakeholder: For the stakeholders found in phase 1, market parties were identified and their interests as well as perspective on BIPV were defined. Information was acquired from desk research.
3. Determine relationship(s) between involved parties and their position within the ecosystem: This step visualizes how the stakeholders are related to each other within the BIPV sector. Points of differentiation for primary stakeholders, secondary and tertiary stakeholders were used as a guidance.

2.2. DESTEP-analysis (methodology)

A DESTEP (demographic, ecological, socio-cultural, technological, economic and political-legal) analysis gives an idea of the environment the BIPV sector is operating in and what developments, trends and uncertainties it faces. It provides a systematic analysis of the external factors the sector is subjected to [9]. Each category was qualitatively described by means of desk research on all impacts that are applicable to the BIPV sector. Main sources for the desk research were the statistical databases of CBS, the World Bank and Eurostat, as well as scientific literature and reports from the International Energy Agency (IEA).

3. Results

3.1. Stakeholder analysis

1. Inventory of involved parties

The identified parties are presented in Table 1 and checked with the preference of SMEs that are active in the BIPV sector of the Netherlands [10].

Table 1. Inventory of parties that are involved in the BIPV sector, classified according to the Triple Helix model [8]

Triple Helix parties	BIPV stakeholders
Government	European Union; Dutch government; Provinces & Municipalities; Federation spatial quality & Design Review Committees
Industry	BIPV manufacturers / suppliers / wholesale; Construction industry (contractors, material suppliers; PV-module installation; architects); Industry associations
Academia	Research institutes; Universities
End Users	Housing associations and their tenants; Business Rental (office spaces); Private homeowners

2. Interests of involved parties

A detailed description of interests, perspectives and challenges for the various market parties in BIPV in the Netherlands is given in Table 2.

Table 2. Interests, perspectives and challenges for BIPV stakeholders in the Netherlands.

Stakeholder	Interests, perspective, challenges and market parties
Academia	
Universities	Universities serve as a supporting party within the BIPV ecosystem. They hold and develop extensive knowledge on technological developments for PV and BIPV and sustainable construction by conducting independent research. This can be valuable input for the BIPV industry. Furthermore, they provide education on (BI)PV technology and applications to provide the necessary skills for future (BI)PV professionals.
	Regarding the relatively small scale on which BIPV is currently implemented, it remains a challenge to give sufficient attention to BIPV within study, education and training programmes (Berenschot, 2015). Utrecht University therefore has been granted an Erasmus+ project, together with institutions from Austria, Germany and Cyprus, to develop an innovative and multidisciplinary, high quality course for BIPV [11]. This illustrates the growing interest in BIPV in the academic world.
	Parties: Avans Hogeschool; Hogeschool Zuyd; Technical Universities of Delft, Eindhoven and Twente; and Utrecht University.
Research Institutes	Research institutes have a position similar to universities. They conduct independent research projects that are often commissioned by external parties, e.g. government or industry. Therefore they are very important for the creation and maintenance of a strong (national) knowledge base.
	Subsidy schemes are an important driving force behind the research. This provides a challenge to continuously secure funding to support parties in their research activities.
	Parties: Solar Energy Application Centre (SEAC); TNO; ECN; and Solliance.
Industry	
Manufacturers & Suppliers	The amount of BIPV manufacturers is growing. This mostly concerns existing companies that are originally either solar module manufacturers or manufacturers of building parts (e.g. roofs and façades). The BIPV suppliers work closely together with the manufacturers or sometimes comprise even the same entity. Currently, suppliers are mostly SMEs that provide a full solar roofing or solar façade solution.
	This overview of BIPV manufacturers and suppliers is far from complete [3]. Since BIPV is a fast developing field, the number of parties involved is changing rapidly as well.
	Parties: AERspire; BEAUsolar; Centrosolar; EXASUN; Linesolar Orange Solar; Stafier Solar Systems; Scheuten; SCX solar; SolarSwing; Solinso; Synroof; Tulipps; Unidek; Zep BV; ZigZagSolar; Zonnepanelen-Parkstad
Wholesale	For regular PV components the wholesale market is already well established. For example in the Netherlands, the turnover of PV-wholesalers has already increased with 87% in the first three quarters of 2015 [12]. For BIPV components large-scale production is yet limited, since it is currently often designed per specific purpose [1]. This implies that the share of BIPV in total PV wholesale is yet relatively small. To increase the awareness of BIPV it is important that the product is easily accessible; BIPV should therefore become standard stock in PV wholesale.
	Parties (trading mostly in regular PV system components): 4BestSolar; IBC Solar; IkBenRa; Klimaatgarant Solar; Mijn Energie-fabriek; Novasole; ProfiNRG; Sirius Solar Solutions; Zonel Energy Systems
Building energy consultant	In utility building projects, consultants provide advice on criteria such as energy regulation and performance, noise isolation, material saving procedures et cetera. More and more buildings have to comply with BREEAM, LEED, other certification procedures and requirements [13].
	The Dutch Green Building Council (DGBC) can recommend the use of BIPV in the building. It is therefore important that building consultants are familiar with the opportunities of BIPV in (utility) buildings and collaborate with architects.
Architects	An architect designs a building or building component in consultation with the client and a contractor. In this phase decisions are made on the energy neutrality goals of a building and the application of solar energy. It is therefore very important that these parties are familiar with the concept of BIPV and promote its implementation [2].
	Costs of (BI)PV are often expressed as €/Wp. For architects this is not an interesting figure, especially not when the component has a building function. Therefore, expressing costs as €/m^2 has to become the standard for BIPV [14,15].
	Architects do not have a decisive role in the Netherlands. Apart from the general design they mainly provide recommendations and ideas, but the final decision is made by the client or the contractor [13].

Stakeholder	Interests, perspective, challenges and market parties
Contractors	The contractor usually coordinates a project after the design phase and is responsible for realization of the building. It is therefore important that the contractor is familiar with the BIPV industry, regarding collaboration with sub-contractors and suppliers of building material [2]. The main bottleneck is often the availability of sufficient financing to establish the design of an architect. In most cases, when the client and/or contractor are not familiar with the advantages of BIPV, this will be one of the first components that is replaced by a cheaper alternative [13]. This emphasizes the need of awareness creation.
	For the contractors it is also important that BIPV costs are expressed as €/m^2 instead of €/Wp.
Material suppliers	The proximity of suppliers of building materials is important for a value chain, in order to function as efficient as possible. These suppliers are mostly contacted through (sub-) contractors. This however holds for any type of value chain, not specifically for BIPV. What is important in the BIPV market is that the standard building materials can be integrated with the BIPV components, both practically and aesthetically. This can for example also concern the sustainability of the building materials. Acquiring aesthetical and sustainable materials at a suitable price level can be a challenge.
PV-module installation	The installation of BIPV-modules in a building requires electricians who have expert knowledge in PV-connections as well as in construction. Compared to regular PV, the installation costs for BIPV increase because a larger number of usually smaller components needs to be installed at a relatively larger area. This requires more interconnections and electrical wiring [16]. Furthermore, the roof is not only required to produce electricity, but also to be weatherproofing. On the other hand, the efforts for covering a traditional roof are diminished. It depends on the BIPV supplier whether they are limited to delivery of the BIPV modules or also include the installation.
Industry associations	Organizations that cover specific branches exist in most countries, but mostly cover the entire solar industry, or at least multiple niches. The European industry association for PV and BIPV is Solar Power Europe, led by the industry, and the European Photovoltaic Technology Platform (EU PV TP), led by the industry and academic and research institutes.
	Parties: Duurzame Energie Koepel; Nederlandse Vereniging Duurzame Energie; Holland Solar; Uneto-Vni
Government	
National government	The role of the government will be mainly supportive and to serve as an example. This will be further discussed in the DESTEP-analysis.
Federation spatial quality	The federation of spatial quality (Dutch: Federatie Ruimtelijke Kwaliteit) has the goal to promote and improve the quality of the built environment. This quality can be expressed in terms of safety, health and attractiveness of the surroundings. In most countries this concept is merely incorporated in the building code and not further addressed by a specific body.
End users	
Housing associations + tenants	Housing associations can decide themselves to implement BIPV in their buildings, but can also be influenced by the wishes of their tenants or the municipality. Housing associations are responsible for energy supply being sustainable and affordable, which can be realized by investments in the real estate to decentralize electricity production [17]. Furthermore, housing associations have a social role since other buildings within the residential environment can be influenced by their decisions.
	In the Netherlands, both private rental and rental organized by housing associations is abundant. Housing associations in the Netherlands can almost be seen as a governmental body with specific rights and duties [13].
Business rental (office space)	Buildings that are rented for business purposes can be important initiators of BIPV projects. The building can have various purposes, e.g. office space for both private companies and the government, parking area, shopping area or a venue for events. The building can also be an indication of how much attention a business has for green activities. BIPV can therefore contribute to the message a business wants to convey [18].
Private homeowners	Various reasons exist for private individuals to invest in renewable energy projects [19]. Homeowners can for example be interested in the technology, want to produce electricity themselves, have the wish to become self-sufficient, want to demonstrate a green or dedicated image to their environment et cetera. Through these visible investments, they can influence their direct environment. The amount of private homeowners that implements (BI)PV in their home is growing in the Netherlands [20].

3. Relationships between involved parties and their position within the ecosystem

The stakeholders can be made as shown in Fig. 1. Primary stakeholders are the ones who initiate the main activities and are responsible for execution of the work; they are displayed in the center of Fig. 1. The second shell represents the secondary stakeholders, who are the key partners without whom operations would not be possible, e.g., direct suppliers or customers. The tertiary stakeholders mainly have a supporting role and are positioned in the outer shell. Some stakeholders show overlap between the shells, e.g. contractors are a customer in the first place but also highly influence the product output.

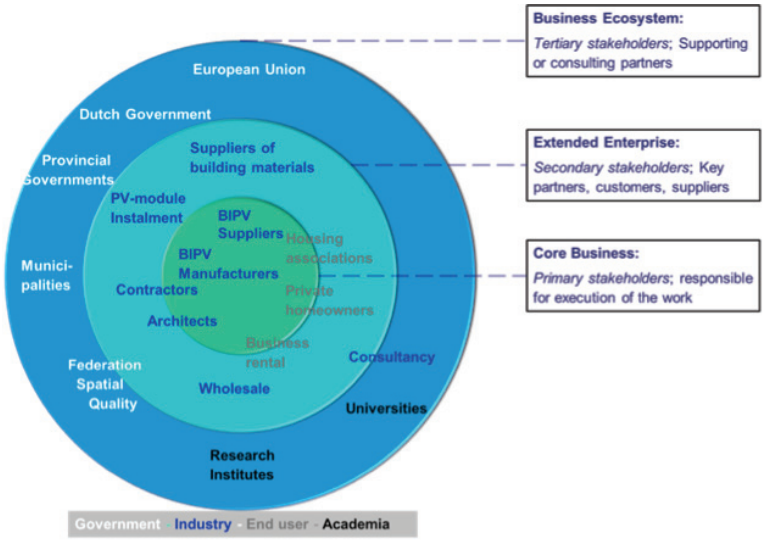

Fig. 1. Stakeholder map for the BIPV ecosystem

3.2. DESTEP analysis

Table 3. Summary of relevant impact factors on the Dutch BIPV ecosystem for each category of the DESTEP-model.

Parameters	Findings
Demographic	0.4% population growth per year until 2020 [21];
	84% of population lives in urban areas [22];
	Unemployment rate decreasing. 7.4% in 2014 [23];
	67% of households are homeowners [24]
Ecological	11 tonnes CO_2-emissions per capita per year [22];
	Increasing temperature trend [25];
	Annually 1,521 solar hours and 1,000 kWh/m^2 solar radiation [26]
Socio-cultural	Adequate level of environmental concern [21,27];
	~23% of expenditures on Energy & Housing [21];
	Transition relationship citizens – government [28]
Technological	Further automation of processes and digitalization of information [29];
	Evolution of digitally connected customers, leading to different dynamics in relationships and transactions. Marketing channels are becoming more and more digital [30];
	New internet revolution: more appliances and machines are interconnected to communicate and exchange data [29,30];
	The lack of people with a strong IT background is a serious problem for many industries. This inhibits them to make the right technological decisions and to harness the right emerging disruptive technologies at the right time.
Economic	Recovery from economic crisis; 0.9% economic growth in 2014 [31];
	Growth is projected for export, overall investments and expenditures of consumers [32];
	Increasing trend house prices [23,33]
Political-legal	Decentralization of tasks and responsibilities [28]
	Energy Agreement objectives: annually saving 1.5% in final energy consumption; increasing the share of renewable

	energy to 14% in 2020 and 16% in 2023 and focus on energy performance built environment [34]
	Support programmes: SDE+, Green Deals, IPC, SIB [35]
	All houses have an (indicative) energy label [34]
	Aesthetics reviewed by Design Review Committee [36]
	Technological standards reviewed by NEN, IEC and CENELEC [37]
	Institutions: Solar Energy Application Centre, Solliance, Holland Solar, Hogeschool Zuyd

4. Discussion and Recommendations for further Research

The developments in the BIPV market are dependent on market drivers and market restraints. Market drivers that are applicable to PV in general are the rising energy demand, the increasing costs of fossil fuels, the increasing need to differentiate the energy mix to ensure security of supply, the increasing environmental concerns about fossil-fuel based energy, and government subsidies and financial incentives. Examples of market restraints are the high reliance on government subsidies and incentives, relatively high PV electricity costs and high administrative barriers in some countries [15].

For BIPV specifically, it was found throughout this research that market drivers can be found in the perceived aesthetic benefits of BIPV and the need for energy efficiency and renewables in the built environment to achieve net zero energy buildings. Market restraints however are the higher costs compared to regular PV, low awareness of the public, the government and the construction industry, the limited collaboration between the PV- and construction industry, and the compatibility with existing buildings and building practices. Table 4 proposes ways to deal with these challenges and gives some ideas for research topics in this field, based on the information that was acquired in the Stakeholder- and DESTEP analysis and some additional sources.

This research focused on the situation for BIPV in the Netherlands. This has provided many insights, however in order to compare the Dutch BIPV sector with that in other countries, additional research on other countries would be essential. This study therefore mainly serves as a starting point.

The stakeholder analysis provides a rather complete overview of the parties that are involved in BIPV at the academic, industrial and governmental level at the time of writing. However, since BIPV is a rapidly changing market, it has to be noted that this situation is subject to change as well. Shifting regulatory regimes highly influence the composition of the market and its active stakeholders. This has to be kept in mind when using this information. Furthermore, some information for the stakeholder analysis could not be easily acquired from literature. In these cases, a combination of literature and expert opinions from various parties has been used. This could have led to subjective results.

The DESTEP analysis provides an extensive overview of the recent dynamics in the demographic, ecological, socio-cultural, technological, economic and political-legal factors of the Netherlands. In reality, many more parameters play a role in these factors, some more relevant than others. For the purpose of this paper, however, it can be said that the reviewed parameters are sufficient.

At present, policy measures have been reviewed mainly at the federal level. For all renewable energy measures, including BIPV, it is expected that regulations at the regional or even municipal level are abundant and can be influential. Especially since the Netherlands is subdivided in smaller regulatory provinces, further detailed research on such more locally oriented incentive schemes is recommended to parties who are interested to start business activities.

Table 4. Lessons for the (Dutch) BIPV sector and recommendations for further research

Responsible Parties	Lessons and recommendations
	Government
European and national governments	Governmental regulations and financial incentive schemes need to provide security for the future, and reflect the higher cost of BIPV systems compared to regular PV. Research is needed on harmonization of building codes with energy performance requirements and aesthetics for BIPV to gain ground.
CENELEC and IEC, EU and national governments	General standardization and certification for BIPV needs to be researched and developed, as well as a generally accepted definition. Legislation needs to provide a clear distinction from PV.

Industry	
Manufacturers, suppliers and construction industry	Given the shifting regulatory regimes, research is required on business models that survive without the need of subsidies or that optimally capture subsidies offered in the current regime.
Suppliers, wholesale, construction industry, architects	BIPV needs to follow requirements and developments in the construction sector. This means among others that prices should be expressed per m^2 and not per Wp, aesthetics and materials comply with current standards and the added value of BIPV is understood.
Manufacturers, construction industry	In manufacturing, further automation of processes and digitalization of information needs to be researched and adopted. This should simplify the integration process.
Existing PV industry associations, BIPV industry	An industry association specifically for BIPV needs to be developed at an international level, bringing together BIPV stakeholders to find complementary products and activities and collectively prepare market approaches.
Manufacturers, suppliers, media	Research needs to be done on the advantages and possibilities of BIPV, and outcomes of projects need to be clearly communicated to the public, the government and the construction industry.
Academia	
Universities; educational institutions	Education and research specifically for BIPV needs to be provided at all stakeholder levels, e.g., construction, design and technological development.
Research institutes	Internationally coordinated research and development is already happening, but knowledge sharing remains important in this new and dynamic sector.

5. Conclusion

This research has reviewed the situation for BIPV in the Netherlands. The Netherlands was found to stand out in the following points:

- Interesting support schemes are provided to stimulate SME companies to collaborate in the field of innovation, sustainability and renewable energy, e.g. IPC, SIB and PIB.
- All homes require an energy label and this information is openly accessible.
- Most municipalities have a Design Review Committee (Federatie Ruimtelijke Kwaliteit), showing that aesthetics in the built environment is valued high.
- The Dutch research institutes (SEAC, Solliance and Hogeschool Zuyd) conduct valuable research on BIPV, making pioneering at an international level possible.

The main lessons for the Dutch BIPV sector that can be drawn were summarized in Table 4. The recommendations for further research or practical actions are clustered according to the Triple Helix to provide information on the main responsible parties. Some of these were found to have an international character. The information that was provided throughout this research and the conclusions that were drawn should be taken into account by the government, academia and the BIPV industry when further designing a BIPV (export) strategy for the Netherlands. It has become clear that the BIPV sector crosses national boundaries, and should therefore be reviewed and developed from an international perspective.

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